The Future of Measuring the Light Vector Mesons with the PHENIX Detector

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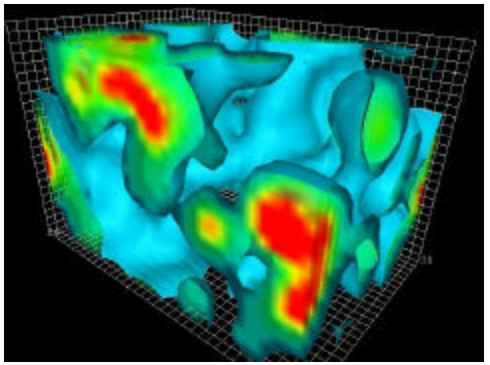
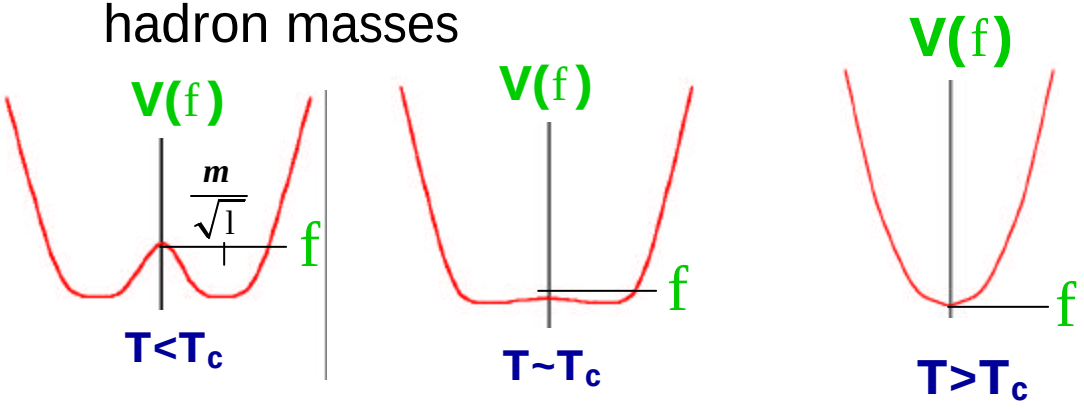
P ioneering
H igh
E nergy
N uclear
I nteraction
e **X** periment

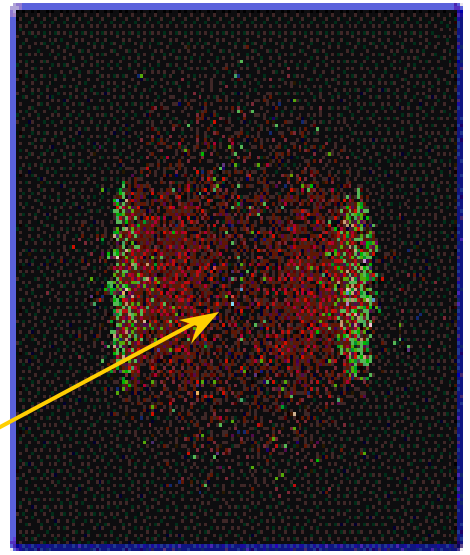
Where does mass (hadronic) come from?



- Space filled with a condensate $\phi = \bar{\psi}\psi$
  - Similar to the higgs field for E-W theory
  - $\bar{\psi}\psi$ - goo of quarks and gluons
  - Couples to quarks and gluons
  - Spontaneous symmetry breaking (I.e. chiral) of the quark condensate at low Temperature generates hadron masses



  - As $T \rightarrow T_C$, mass $\rightarrow 0$
  - How do we heat up the vacuum?
  - RHI collision leaves a region of excited $\bar{q}q$, g – ie hot vacuum



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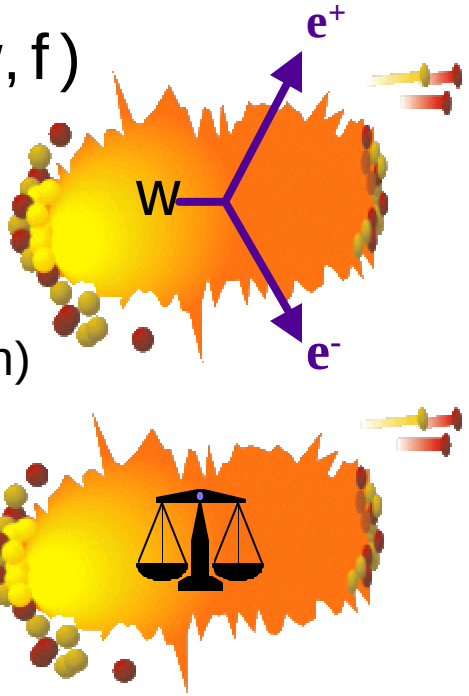
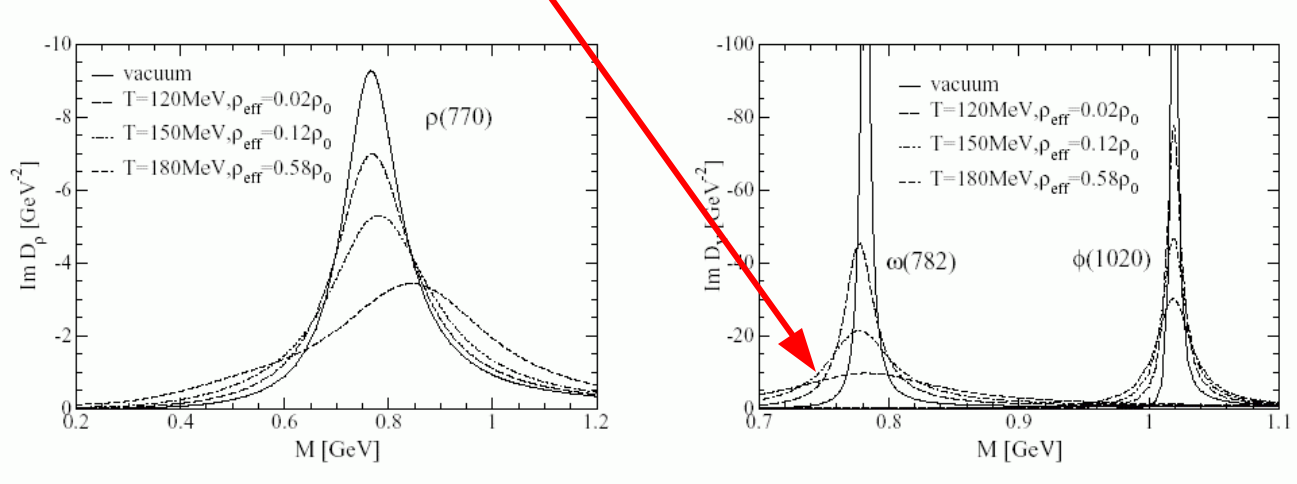
How do you see this?
Vector Meson mass shifts in the dilepton channel

- "Light" Vector mesons are ideal probes (r,w,f)
  - Short lifetime ~ few fm/c
    - Decay inside the medium
  - Electrons (and muons) are ideal messengers
    - Don't interact strongly (e.g. neutrinos from the sun)

  ➔ Like putting a scale to measure mass inside the fireball

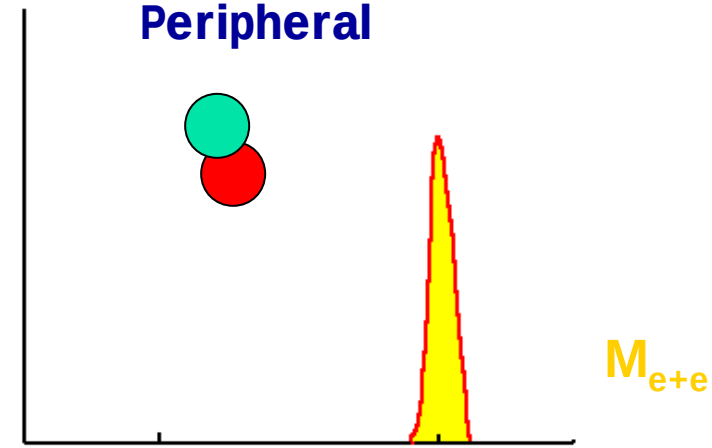


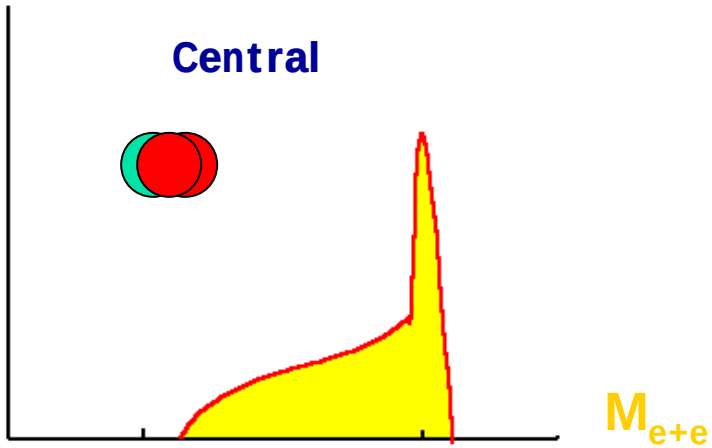
- rwf show a broadening at high T -
  - R. Rapp (PRC(63) 2001 954907)



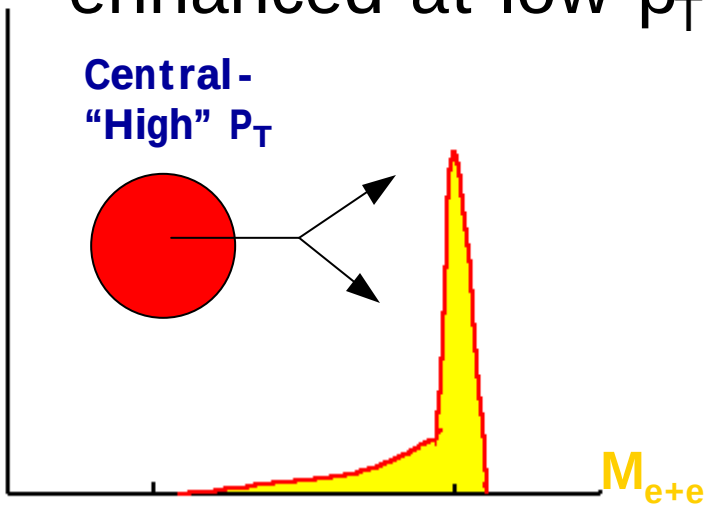
Experimental “Knobs”

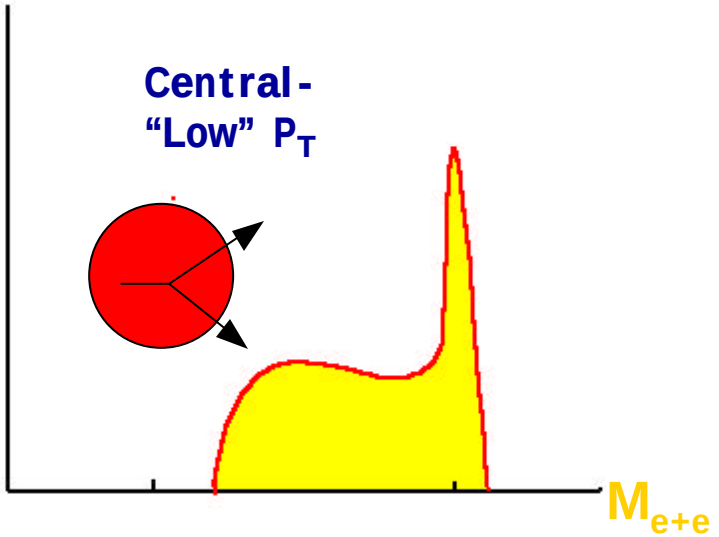
- Signal should increase with centrality





- Signal should be enhanced at low p_T



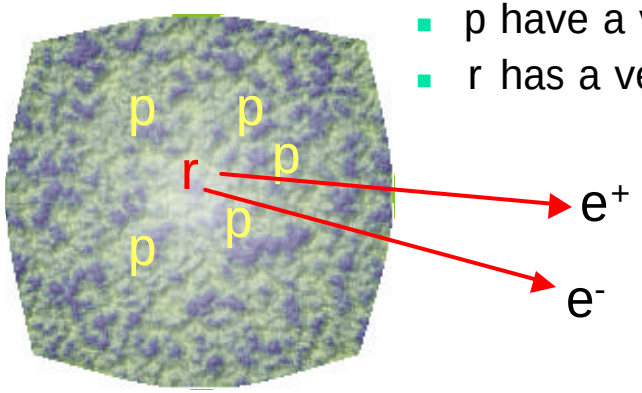


Calculations:comments

- Various approaches
  - Assumptions of
    - Brown-Rho scaling: assumption that hadron masses scale as the quark condensate - essentially from a quark degrees of freedom point of view
    - Rapp-Wambach: Rescattering and cross sections – from a hadronic degrees of freedom point of view
    - This always puzzled me.
- Duality?: hadronic • quark degrees of freedom
  - r (Vector) and A_1(Axial-Vector) become degenerate in hadronic model – I.e. chiral symmetry is restored.
- To actually prove this is not possible at the moment.
- Theorists will depend on experiment to help define the right “degrees of freedom” to use

What measurements are possible?

- Problem – background from dalitz decays and conversions
  - What can we do now?
  - Future : Dalitz rejection via electron ID in a field free region.
  - Critically important to see vacuum values to prove mass resolution is good – I.e. you want to see a “peak”
- New Calculations by Rapp (PRC(63) 2001 954907)
  - Specific to RHIC
  - Uses hadronic degrees of freedom
    - ➔Modification of hadronic resonances (chiral restoration)
    - Strong enhancement of the r (mixed and hadron gas phase)
      - p have a very short mean free path in the hadronic gas
      - r has a very short lifetime (<1 fm)

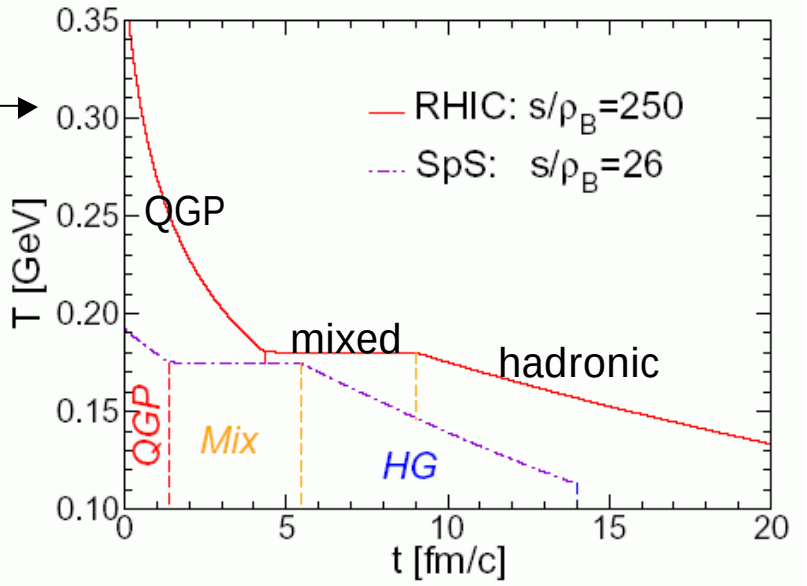


pp®r®pp®r®pp®r®pp®r®pp®r®

↳ e^+e^- ↳ e^+e^- ↳ e^+e^- ↳ e^+e^- ↳ e^+e^-

Time evolution

- Rapp's model has
  - Spectral functions (this is where the interesting stuff is)
    - Many of the medium effects of interest come from interactions with Baryons
    - At RHIC these baryons are mostly from thermal excitations of baryon-antibaryon pairs
  - Time evolution →
- Rapp provides us with
  - Mass and pt distribution from inside medium

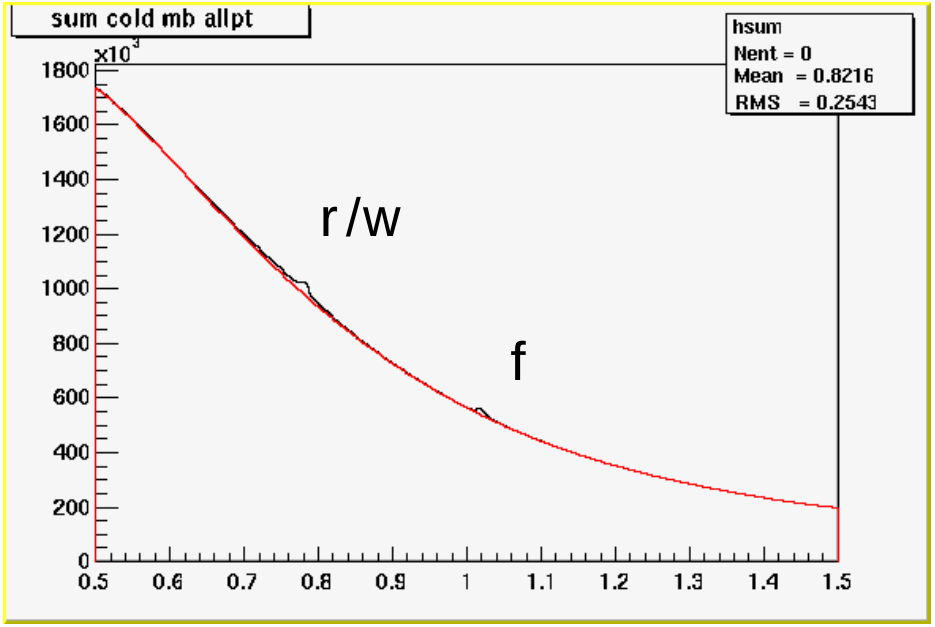


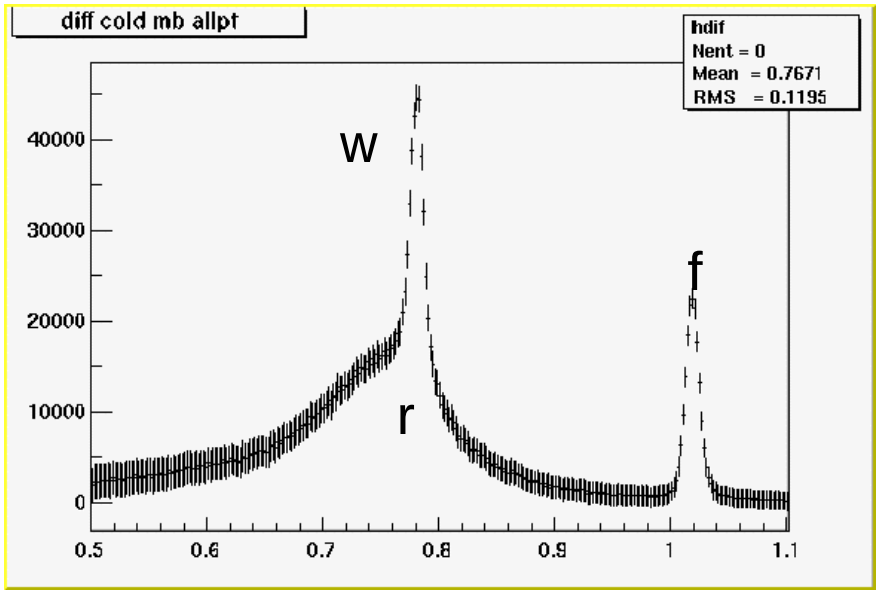
The Exodus generator

- R. Averback has put together a dilepton generator for phenix.
  - Includes
    - sources of dileptons VM(r,w,f,J/y,U), h, h', Charm(singles), dalitz decays, (conversions assumed as scaled dalitz)
    - Acceptance
    - Momentum resolutions effects
  - "Standard" Exodus produces vacuum decays, Rapp spectra govern "in medium" decays.
    - Normalization Checked vs calculation by Rapp.
- PHENIX (Y. Akiba) has made some first measurements of the di-electron background.
- Strategy
  - Incorporate Rapp's model into Exodus
  - Check backgrounds against early PHENIX measurement (rescale)
  - Assume that a mixed event subtraction will work.
  - Assume ~ 10^9 Central events ~4 months perfect running (1-2 yrs)
  - Ignore Systematics, Triggering problems, Assume efficiency is ~100% (It is now ~24% - realistically it may reach 80%)

An example

- Assume ~ 10^9 Central events
  - 1000 events/secx10^7 sec x 10%
  - 10^7 sec is ~4 months perfect running (1-2 yrs)
  - Look at spectra assuming a perfect mixed event subtraction





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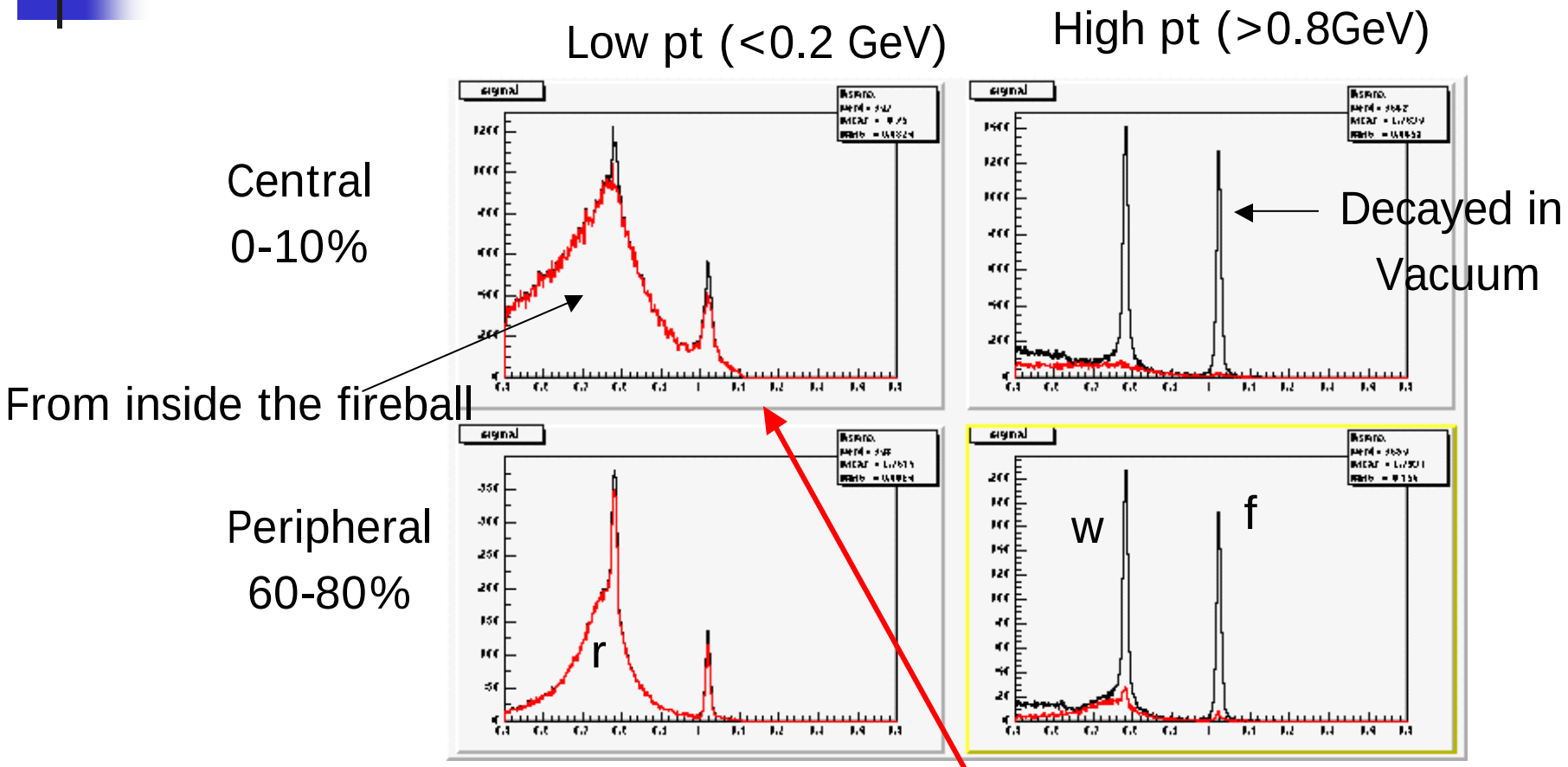
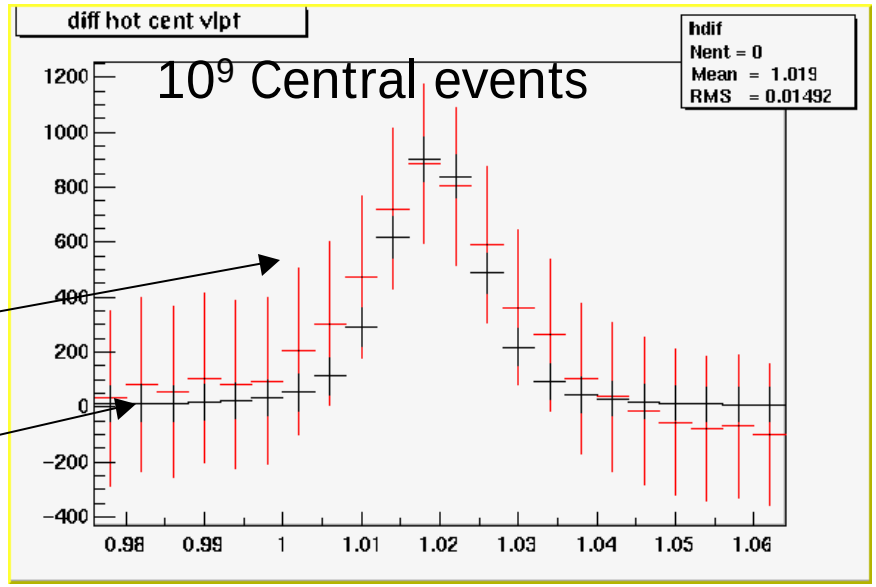
Pt and centrality dependence of the Exodus+Rapp model

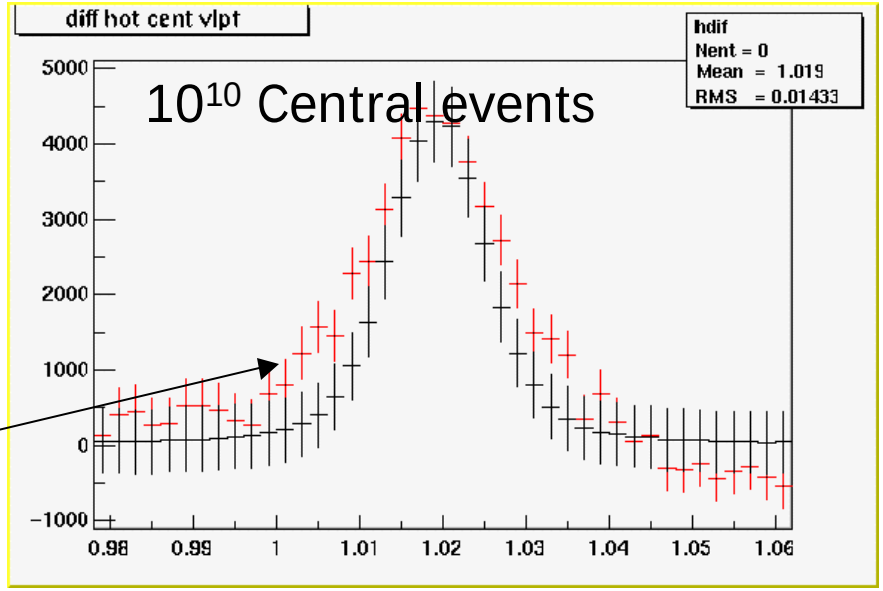


- The signal for “in medium” effects is strongest for central, low pt events
- Peripheral low pt events, show a substantial enhancement of the r from the hadron gas stage

f line shape

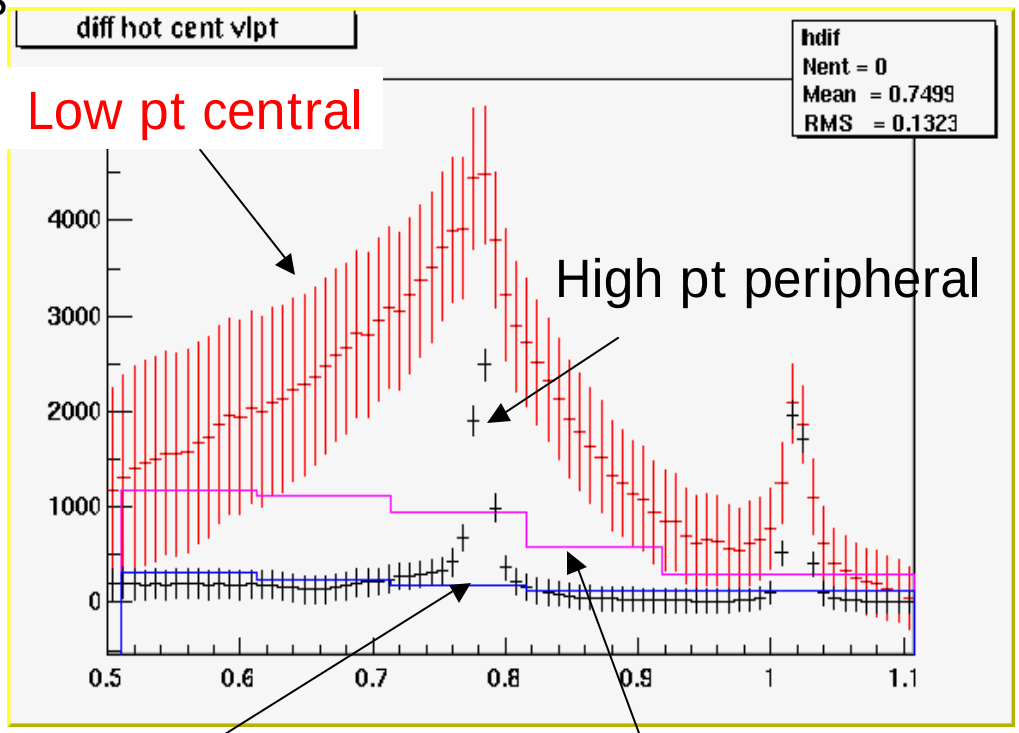
- In Rapp's calculation the f line shape does not change much due to the OZI rule.
- Plots are for
  - Central events pt<0.2 GeV (red) compared to
  - high pt peripheral renormalized (black)
- With statistics of 10^9 Central and no dalitz rejection it is not possible to see the width broadening
- For fun – 10^{10} Events or equivalently – good dalitz rejection
  - Start to get some discrimination





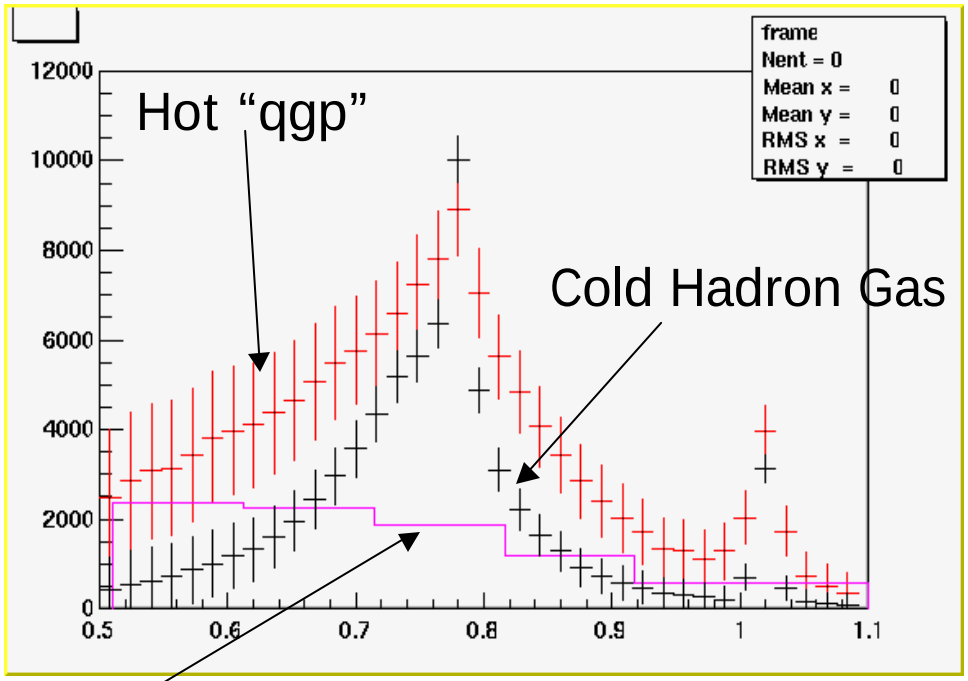
r/w region

- The w is complicated since it sits on the r -nevertheless it should be broadened.
- Even if there is no QGP, Rapp predicts a strong enhancement of the r. (which in itself would be interesting to see – remember the r"clock"?)
  - A problem with this calculation is that correlated charm pairs are not yet in, since the line shape of the r is rather broad. Charm, in many scenarios, is also expected to be enhanced
    - We should be able to identify this if the enhancement is as strong as predicted.
    - But is it a "hot qgp" or a cold hadron gas?



Model comparison – with and w/o “in medium effects”

- In the case of a hadron gas, though strongly enhanced the r should have its ordinary width. The r and w will be separable.
- In the case of “in medium” effects both the r and w will be strongly broadened.

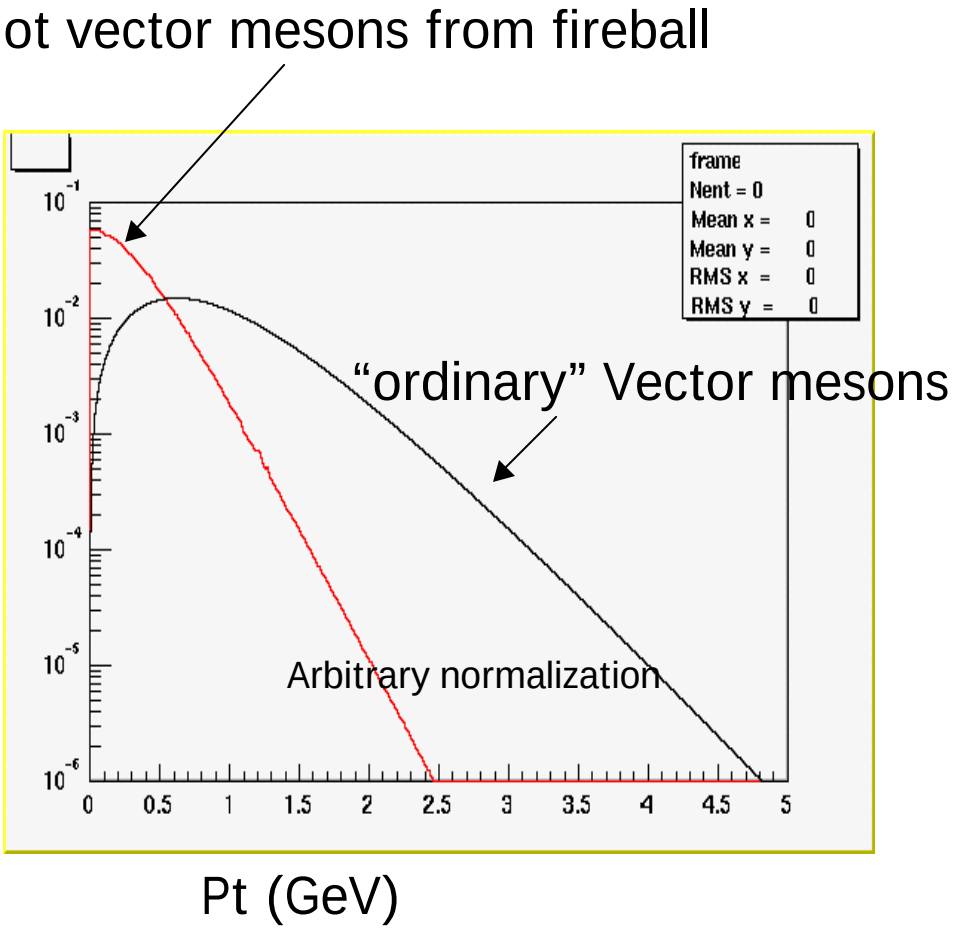


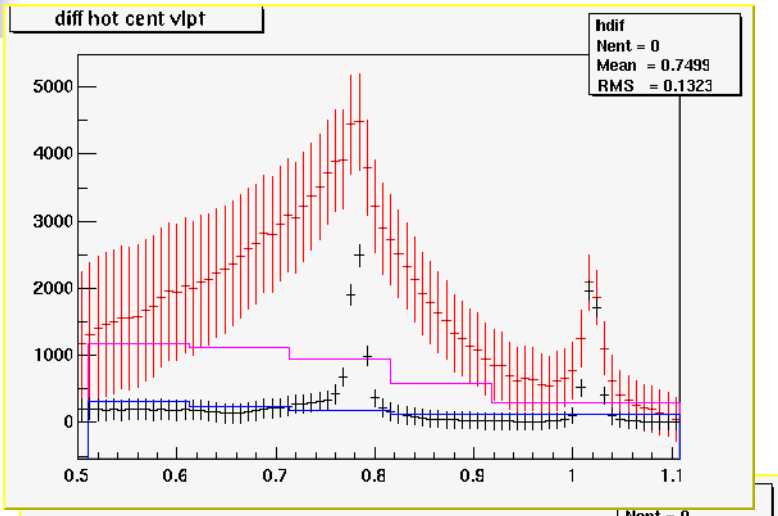
Conclusions

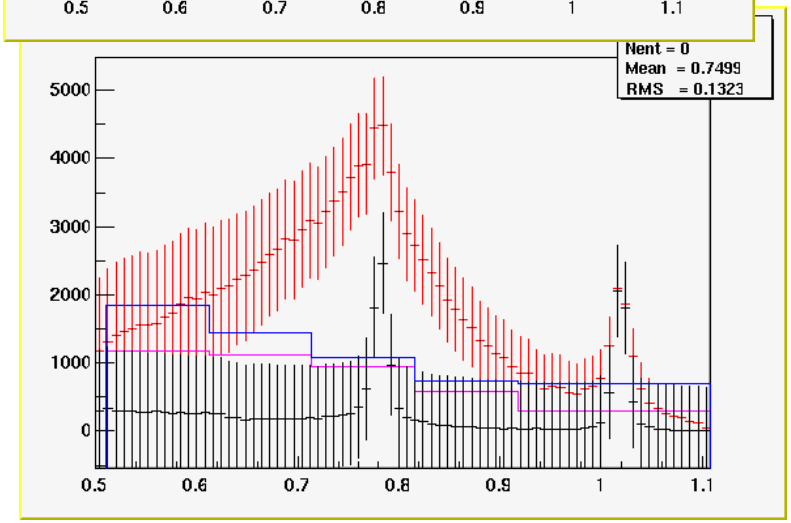
- This was an exercise to get a feeling for what is possible – and assumed a particular model.
- Assuming Rapp's Calculation
  - If the r is strongly enhanced Phenix should be able to see it. We may be lucky enough to see the first hints of chiral symmetry restoration in the r/w.
  - However, the clear signature of chiral symmetry restoration - the detection of width broadening will need very high statistics and/or dalitz rejection
- More studies will be done
  - Addition of open charm pairs directly into Exodus
  - Better incorporation of conversions
  - Incorporation of more detailed distributions from R. Rapp

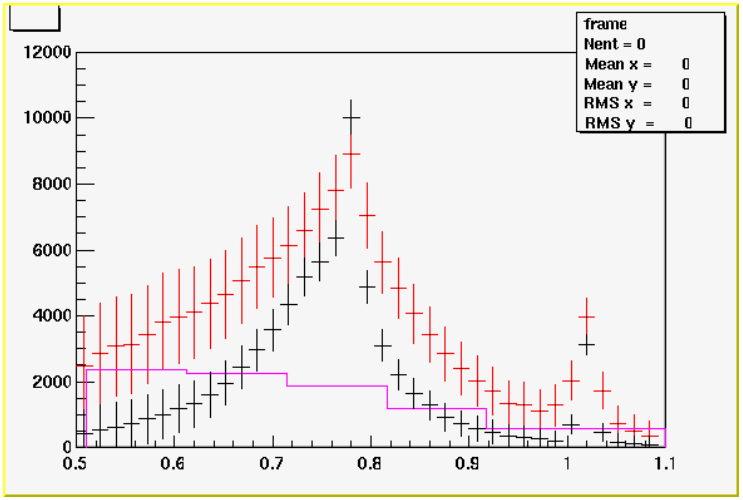
Input Pt spectra

- Pt spectra of “in medium” decays is much softer. The cuts are
  - Pt<0.2 – low pt
  - Pt > 0.8 – “high pt” – the signal is down by a factor of 10.









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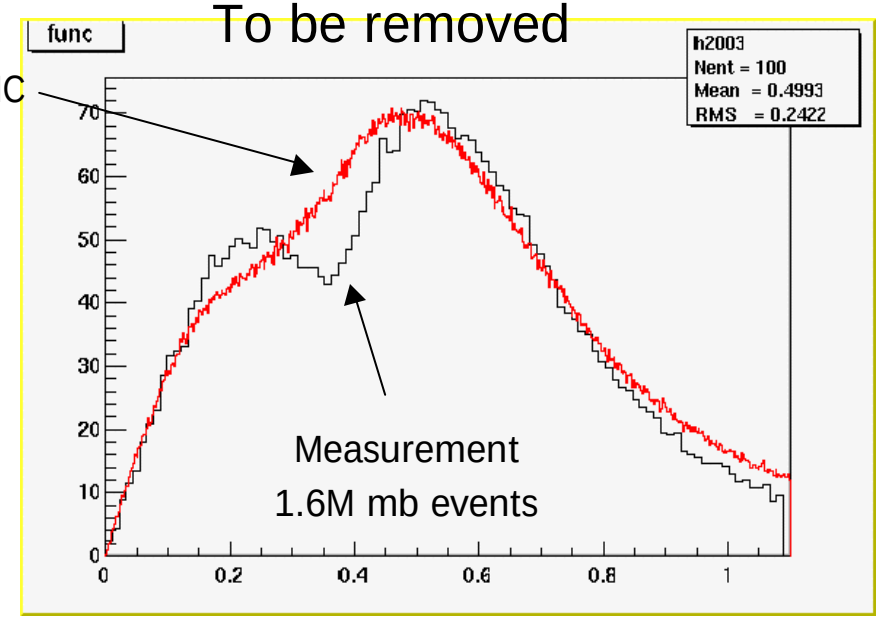
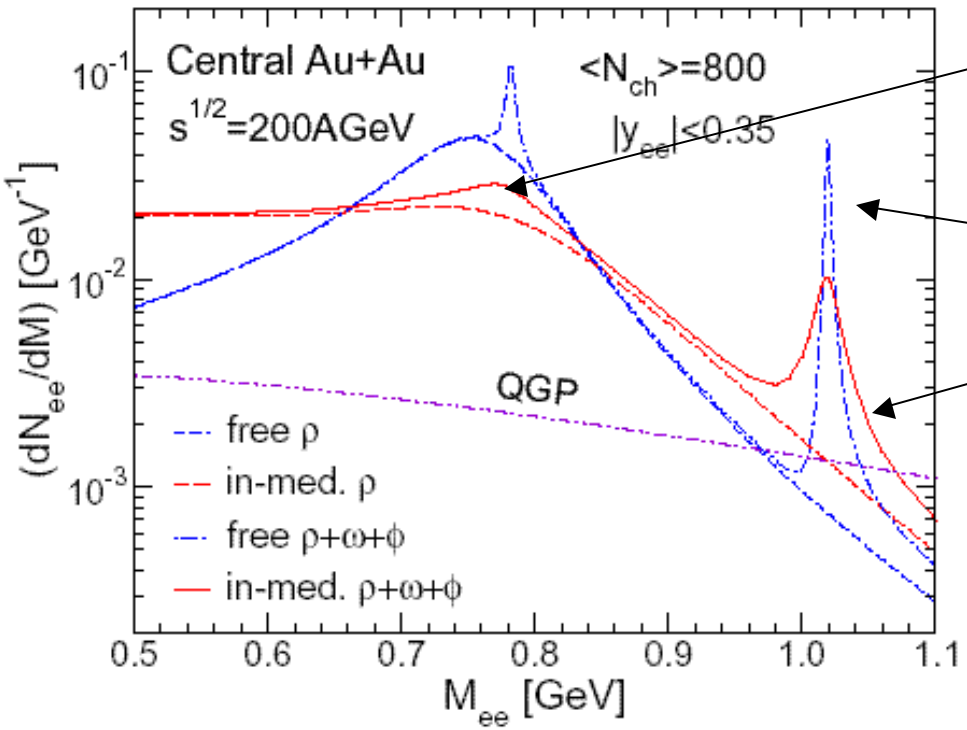
- NOTE – the plot is for internal PHENIX consumption. I believe I must remove it since I don't think this plot has been Oked for dissemination
- I need an overall scale of 4 to match the data- probably about ½ of this reflects the fact that I have no conversions- and I attempt to use this scaling to account for this. It probably means that my charm contribution is too strong. The red curve comes from
  - Requiring (e1 in pbsc(year 1) and e2<800) or the reverse
  - An assumed efficiency of .24 for the two electrons (from akiba's note)
    - (50% east, 80% West, pid~60% for the pair)
    - For the calculation, I scale back up to 100%.

To be removed

Scaled MC



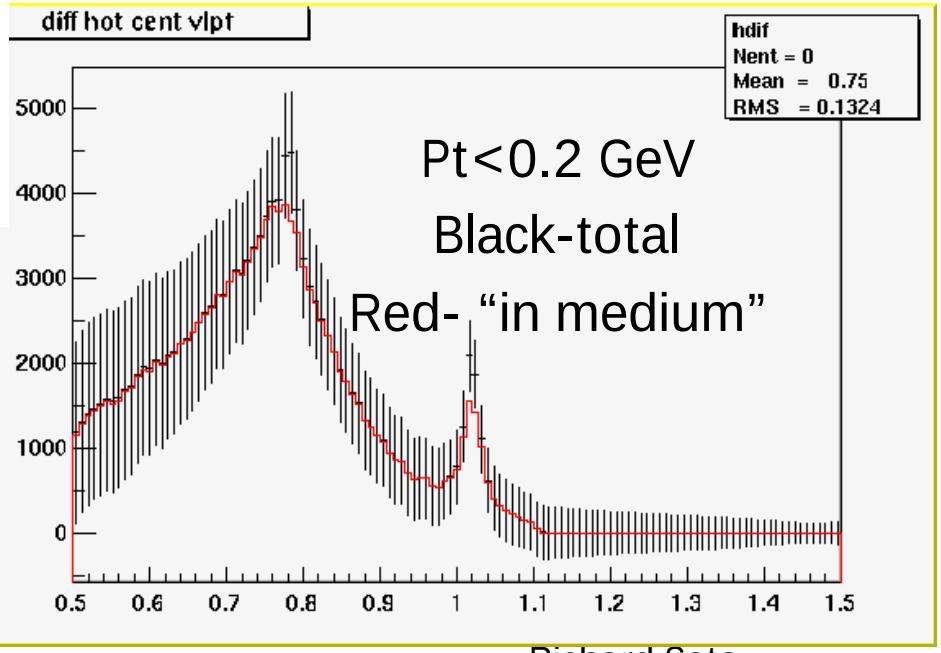
Spectra (theory)



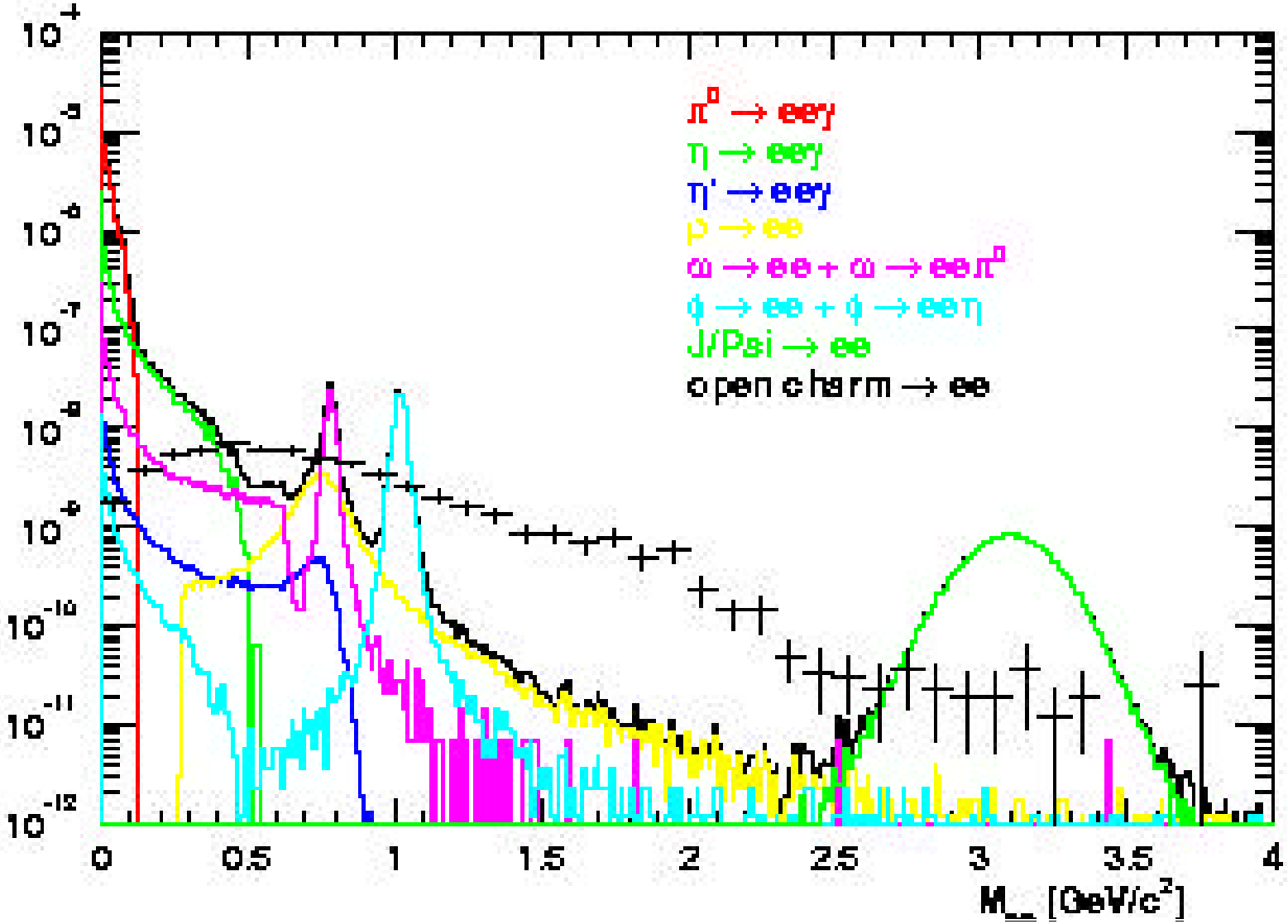
Note strong broadening of w
Pt<0.2 GeV

Free rwf

In Medium rwf



- May be possible to see broadening of r since at low pt, a large fraction of the spectrum is from "in medium" decays



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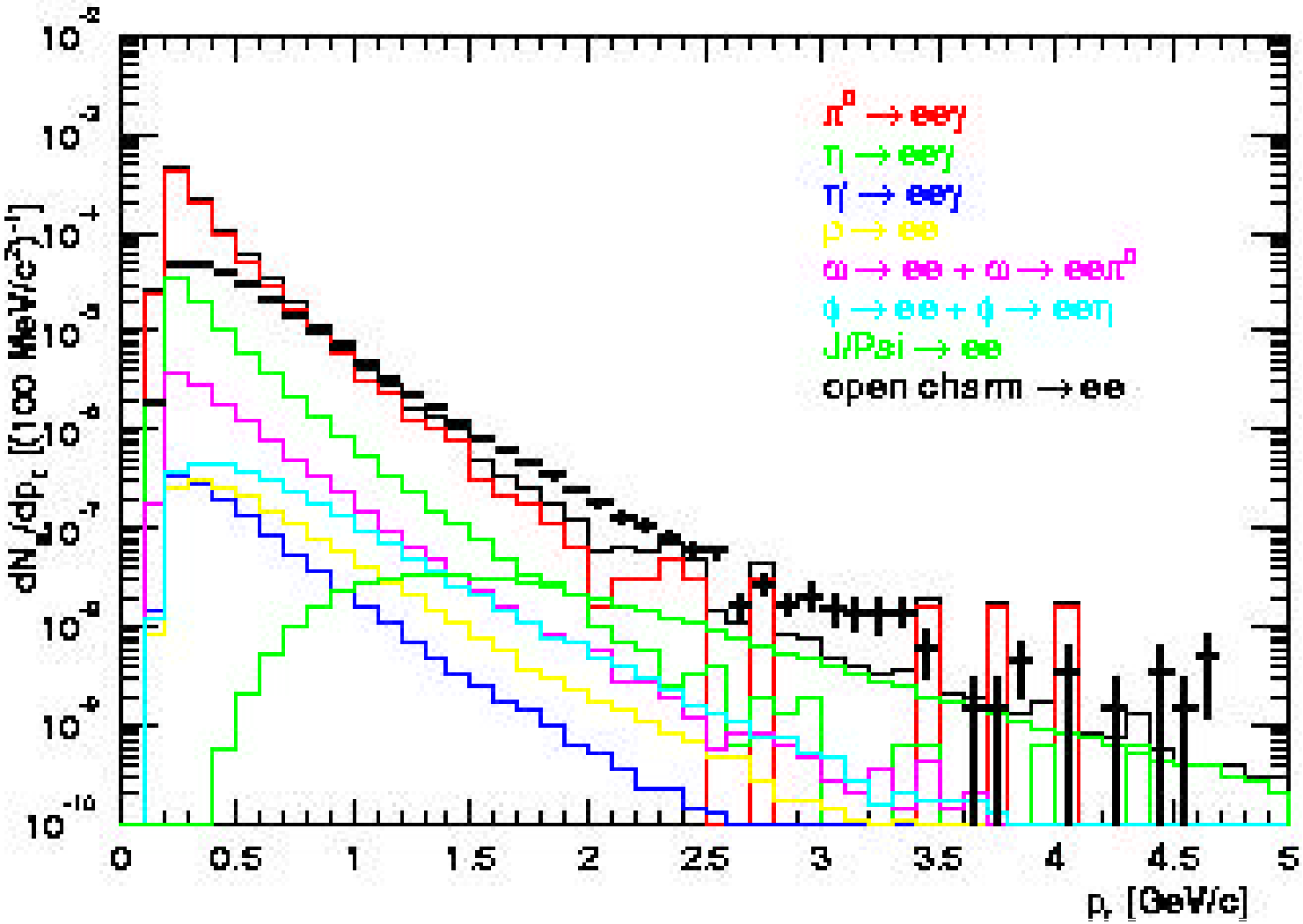

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